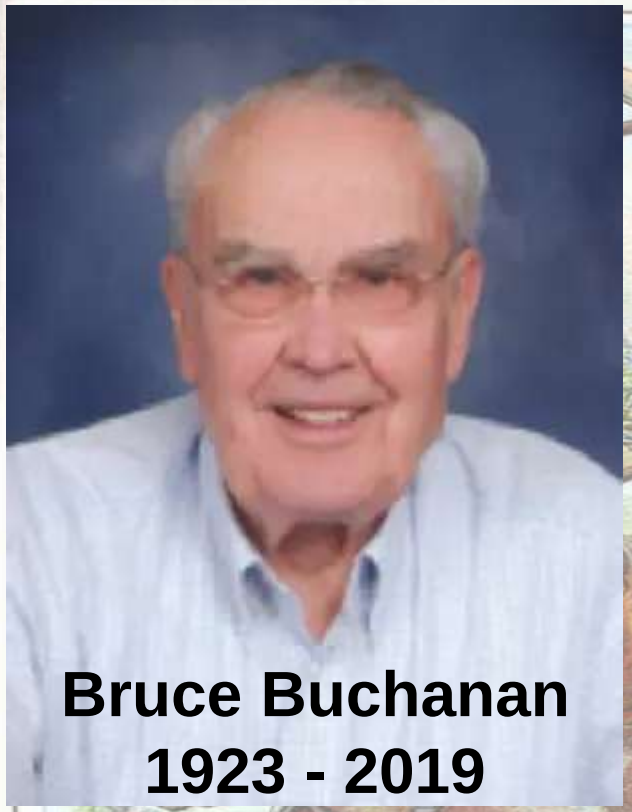


Bruce Buchanan
1923 - 2019

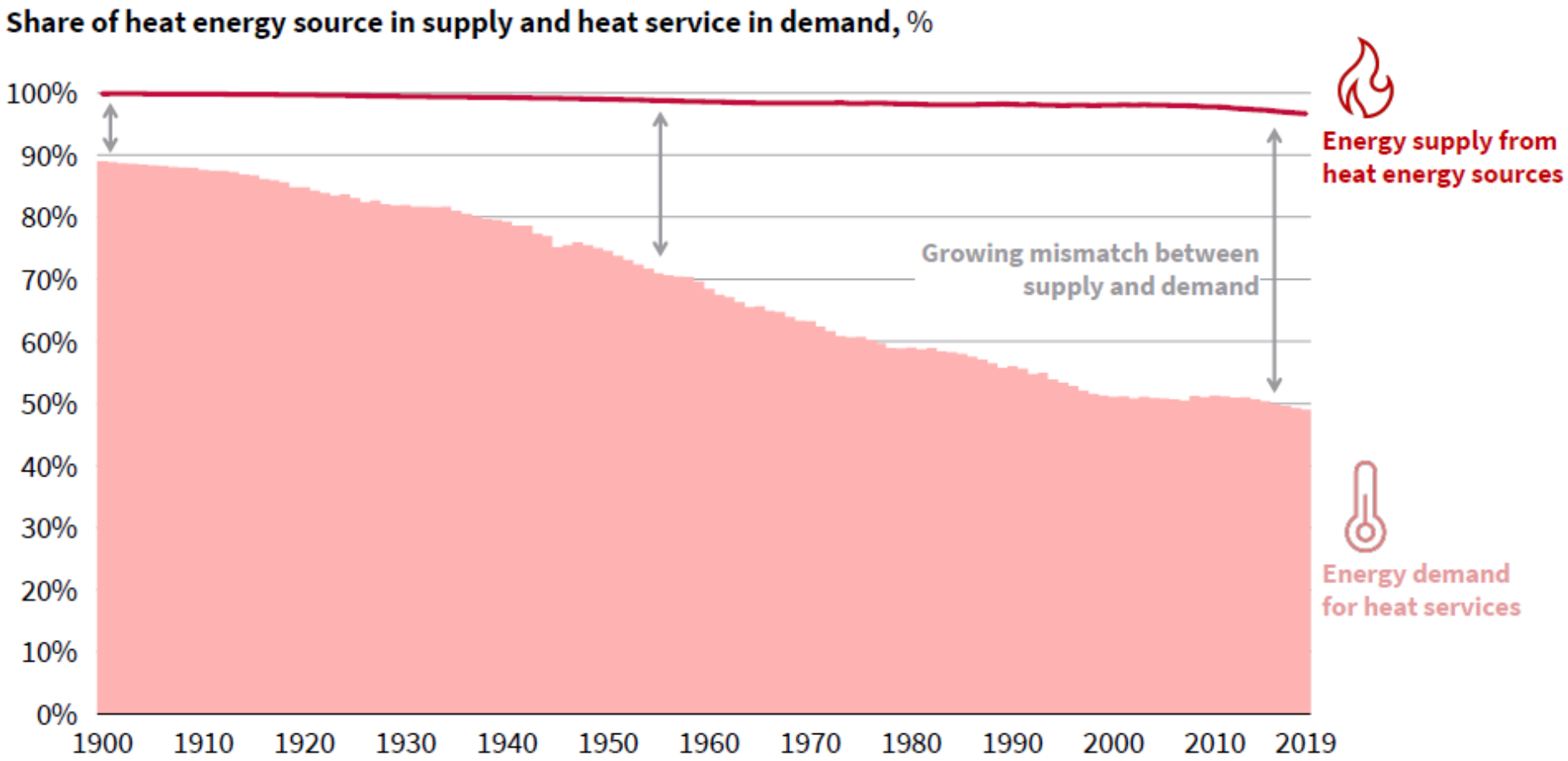
Strategic Farm Electrification: The E-Farm

Eric Buchanan MREC 2025

Energy: The big picture
Farm energy use now
Future farm energy use
WCROC Research

What is an E-farm?

A hundred years of heat energy supply and demand

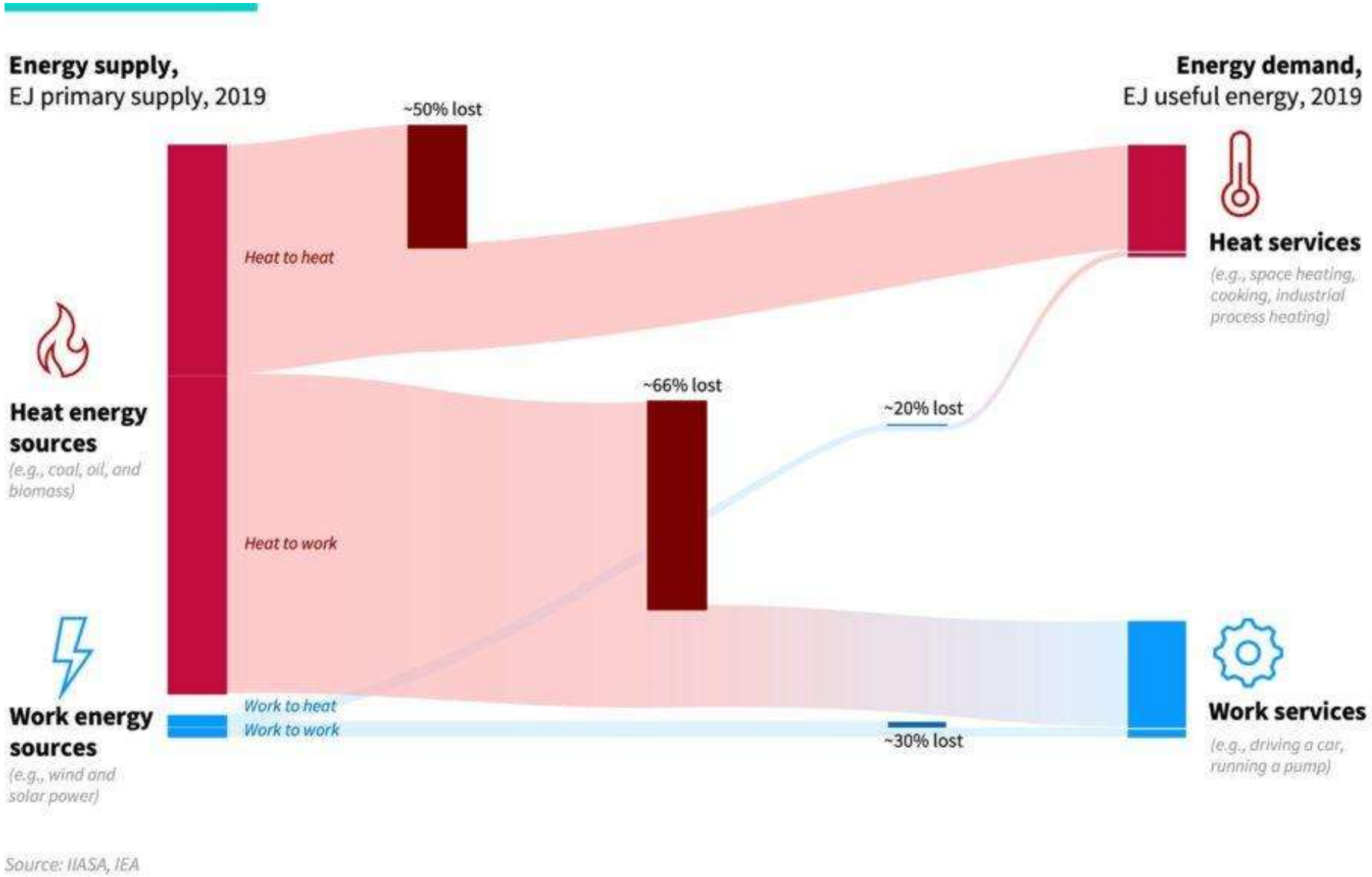


Energy After Fire

Fire has been our primary source of energy for over a million years, providing the essential heat needed to survive.

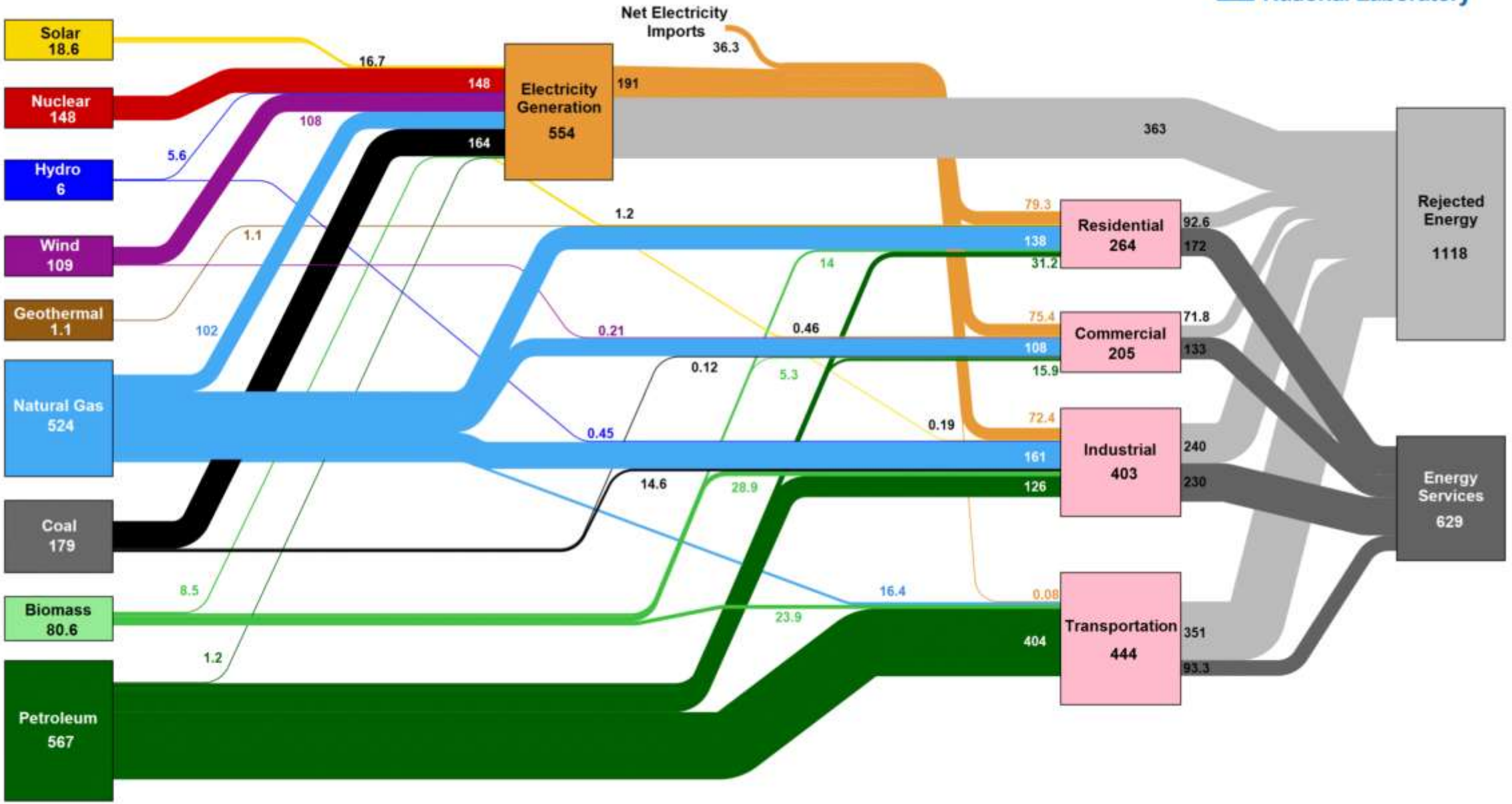
We now require more work than heat

Source: IIASA, Rystad, Energy Institute - Statistical Review of World Energy (2024); Smil (2017) , RMI analysis


Energy supply,
EJ primary supply, 2019
Energy demand,
EJ useful energy, 2019
~50% lost
Heat to heat
Heat energy sources
(e.g., coal, oil, and biomass)
Heat services
(e.g., space heating, cooking, industrial process heating)
~66% lost
~20% lost
Heat to work
Work to heat
Work to work
Work energy sources
(e.g., wind and solar power)
~30% lost
Work services
(e.g., driving a car, running a pump)
Source: IIASA, IEA

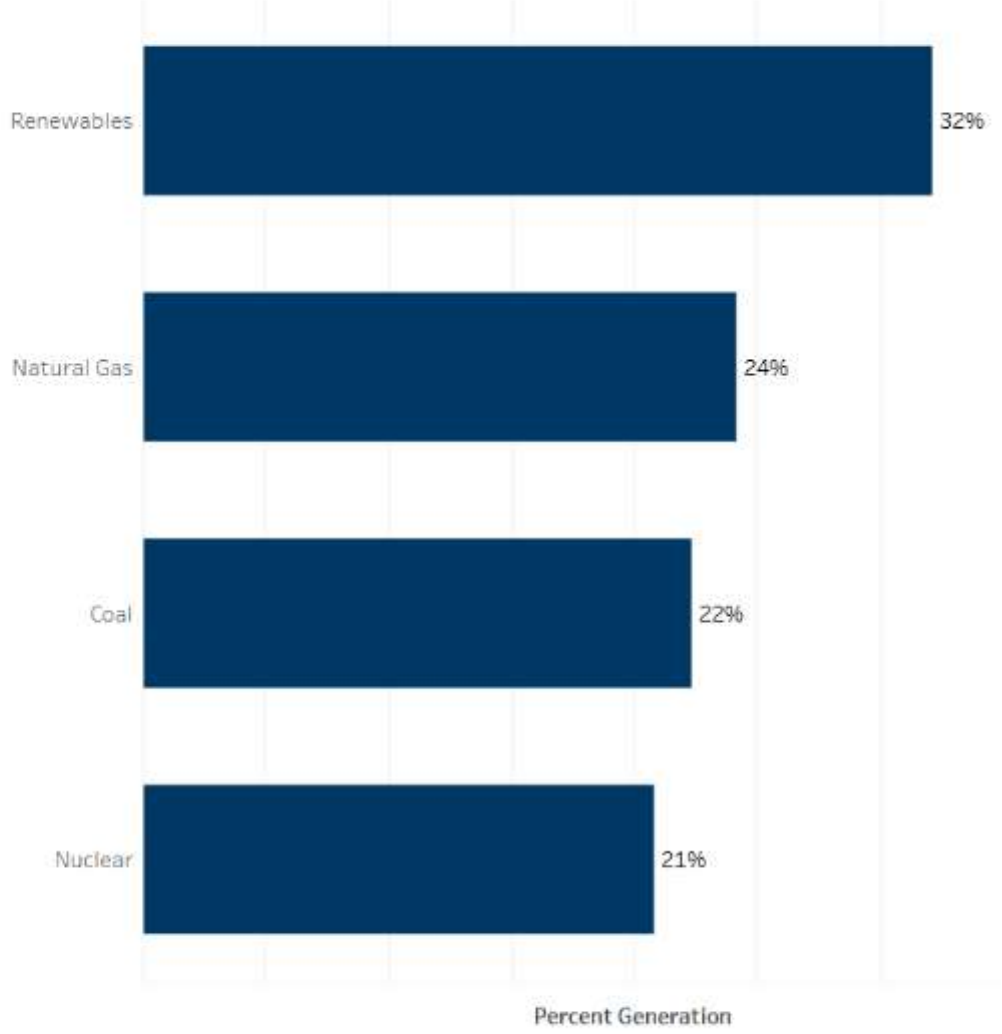
Minnesota Energy Consumption in 2021: 1747 Trillion BTU

Lawrence Livermore National Laboratory



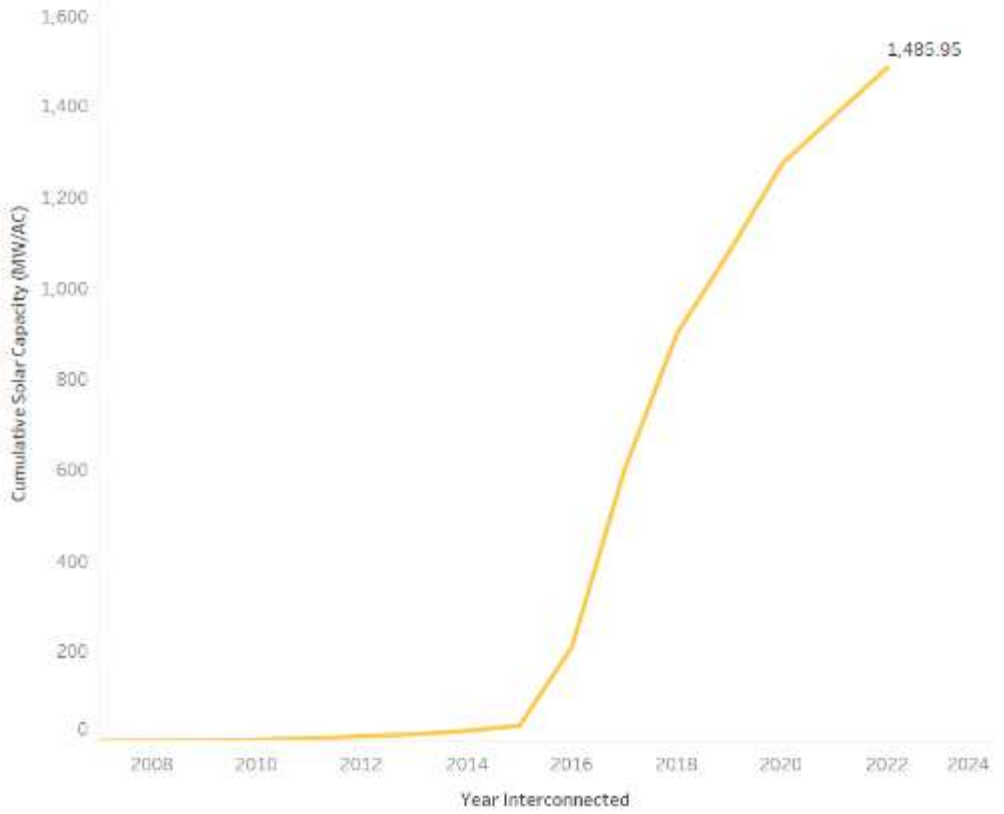
Source: LLNL July, 2023. Data is based on DOE/KIA SEDS (2021). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. KIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 0.65% for the residential sector, 0.65% for the commercial sector, 0.49% for the industrial sector, and 0.21% for the transportation sector. Totals may not equal sum of components due to independent Rounding. LLNL-MI-410527

Electricity Generation in Minnesota



Source: U.S. Energy Information Administration

Cumulative Solar Capacity in Minnesota

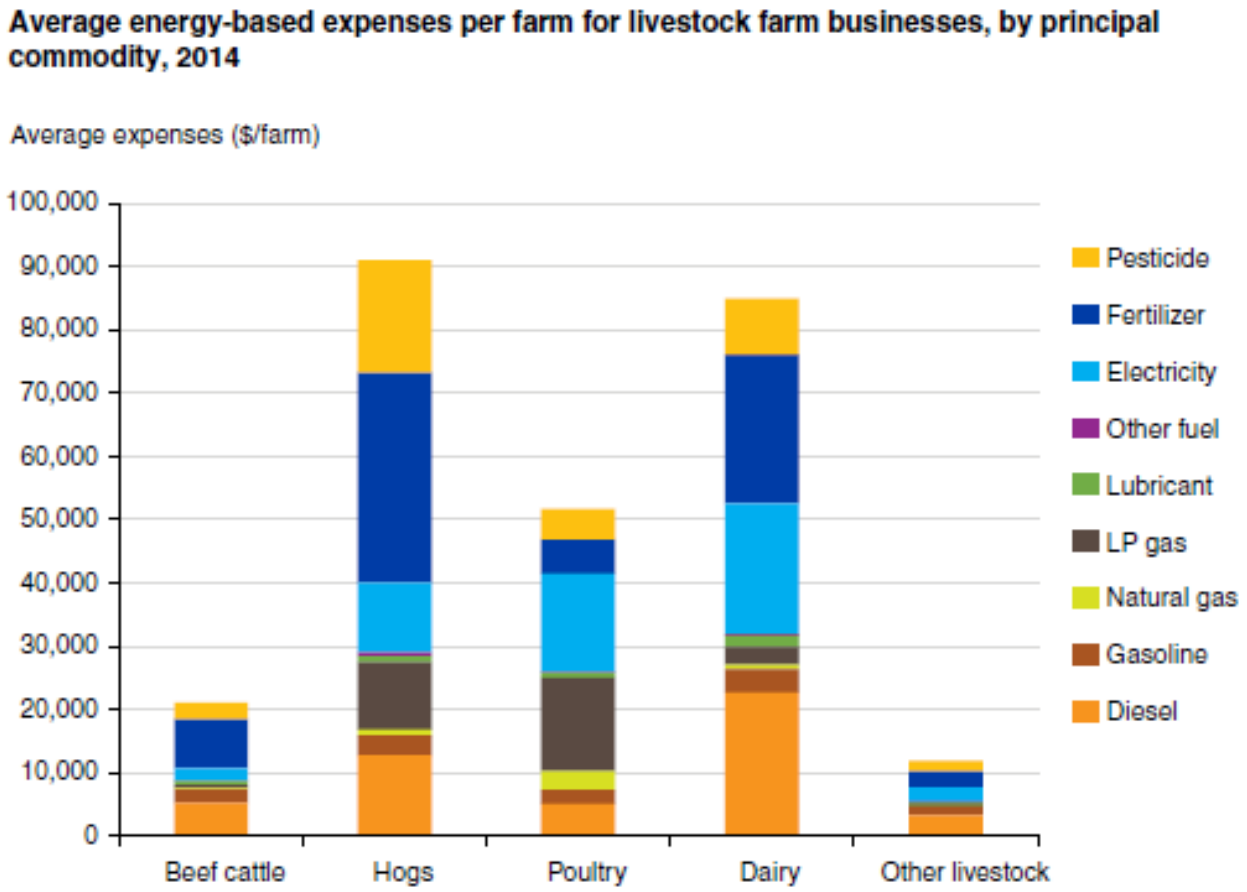


Source: U.S. Energy Information Administration, MN Public Utilities Commission


BUT WHAT HAPPENS ON FARMS?

Farm Energy Use Now

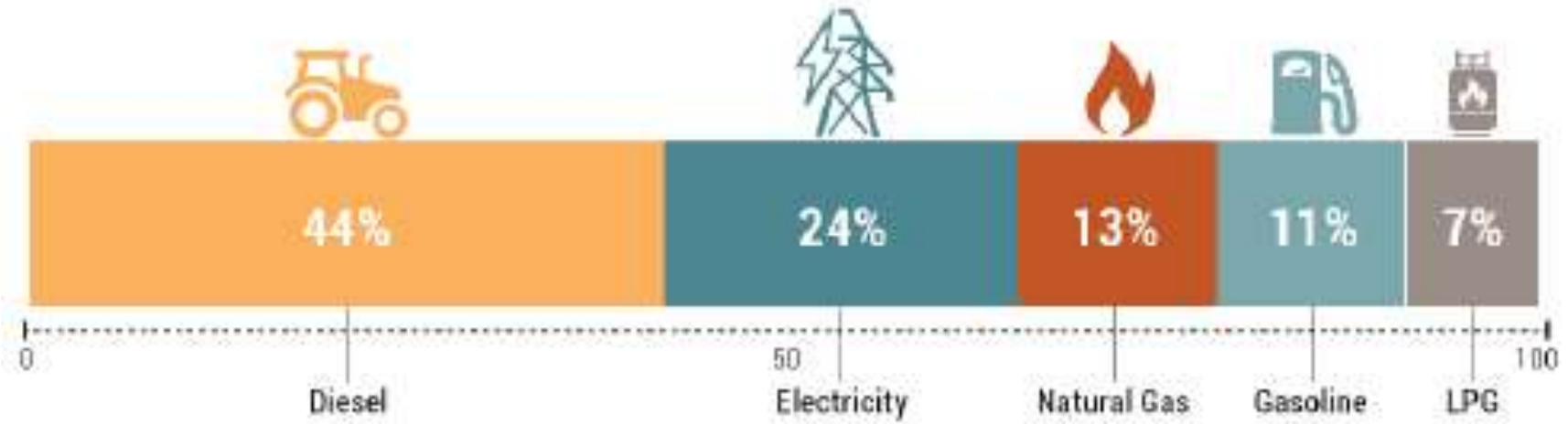
- Direct energy costs are 7 to 16% of farm input costs (USDA 2016)
  - Indirect energy costs are another 16 to 30%
- Farm electrification?
  - Reduce fossil fuel use
  - More efficient
  - Save money



Source: USDA 2014

Farm Energy Use Now

60% of Ag energy consumption is direct



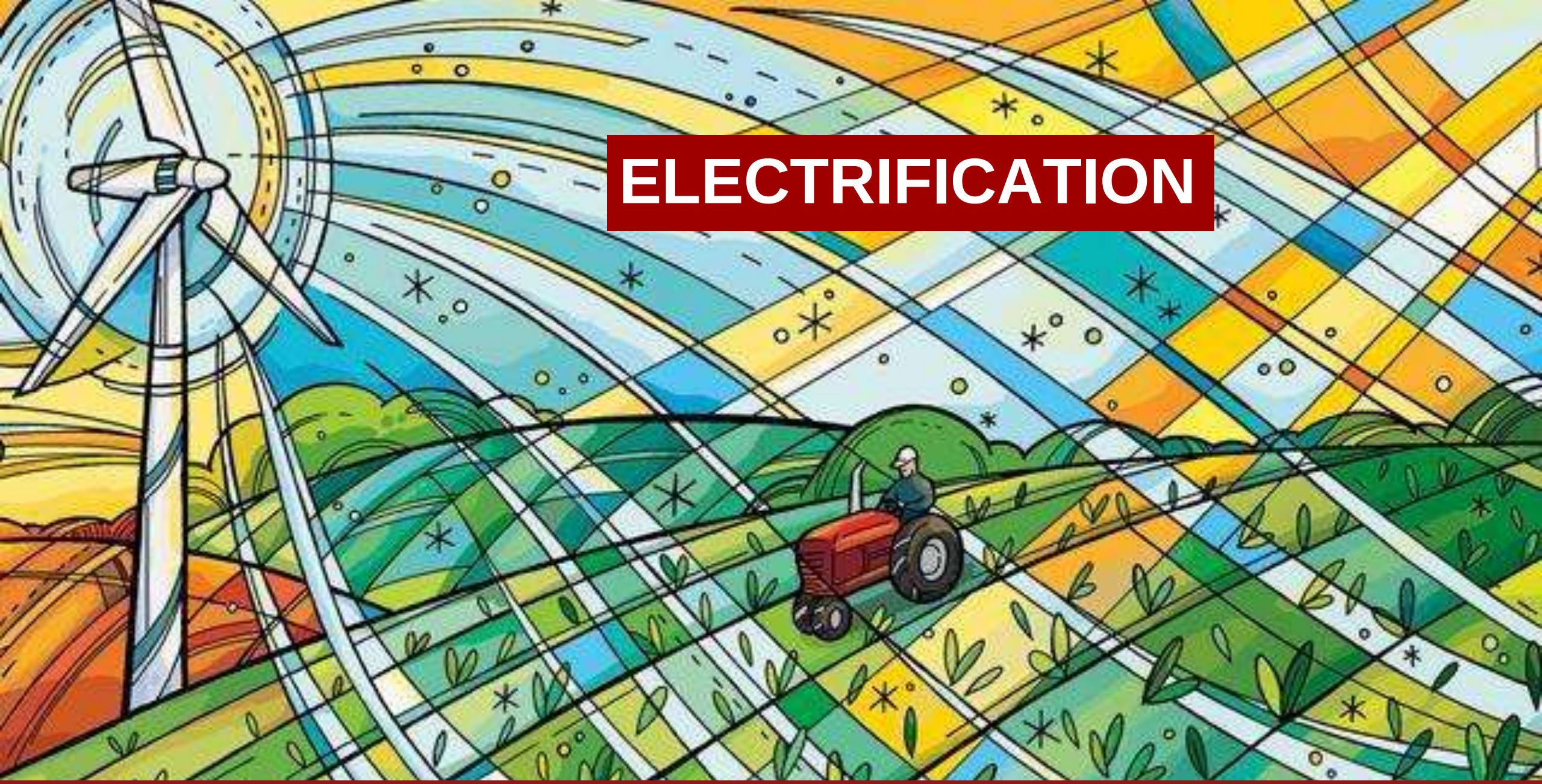
(USDA 2016)

Agrivoltaics

Electrification
- EV's & tractors
- Robots
- Heat pumps

E-fuels (H_2& NH_3)
- Fertilizer
- Grain drying
- Fuel: tractors & power

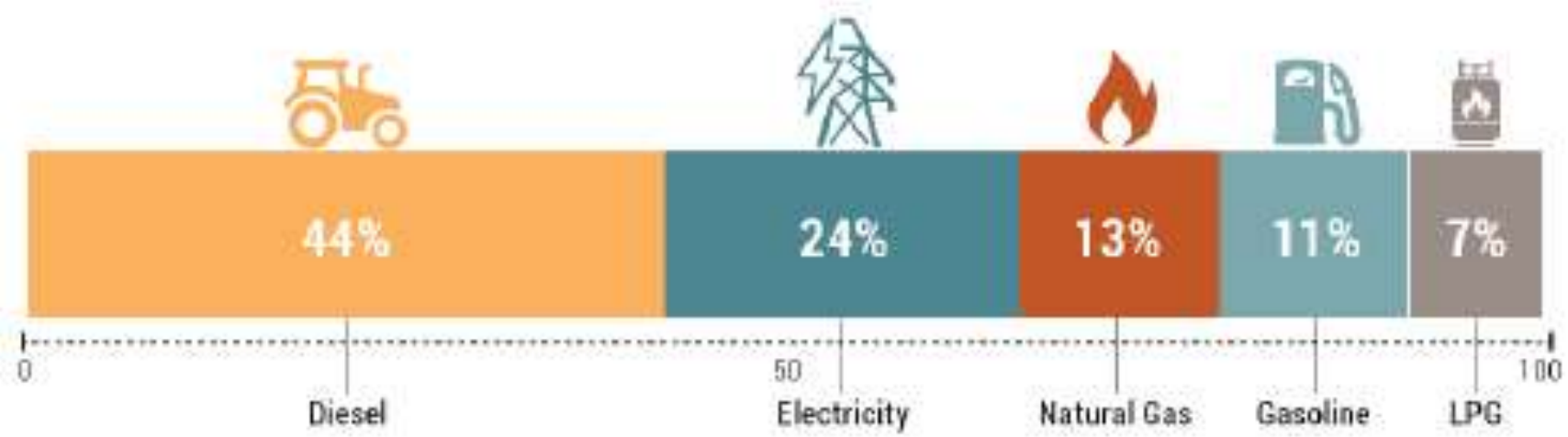
Reduce fossil fuel use in agriculture


ELECTRIFICATION

The Future Farm is Electric

- Why?
  - the Intergovernmental Panel on Climate Change (IPCC) has determined we need to cut CO_2 emissions in half by 2030 to avoid the worst effects of climate change
  - This will be VERY difficult, but can be done by electrifying everything – ***we need to stop burning things***
  - Agriculture emits about 11% of US CO_2 emissions (EPA 2020)

The Future Farm is Electric



(USDA 2016)

Loads to Electrify:

1) Thermal loads (nat. gas & LPG) → **Heat Pumps**
2) Transportation (gasoline) → **EV's**
3) Tractors (diesel) → **Biofuels, NH_3 & Robotics**
4) Chemicals → **Green H_2/Ammonia**

Energy Load - Electrification

- For **thermal loads** use electric heat pumps
  - Burning anything has a maximum coefficient of performance (COP) of 1
  - Heat pumps have a COP > 2 and as high as 4

Air source

Ground source

Energy Load - Electrification

– Example: Cooling milk and heating water in a dairy barn

Energy Load - Electrification

- For **transportation loads** use Electric Vehicles (EV's)

ICE Vehicle	
Average car/SUV	F150
24.5 mpg	14 mpg
$3/gal	$3/gal
12.2¢/mile	21.4¢/mile

Electric Vehicle	
Average car/SUV	F150 Lightning
3.9 miles/kWh	2.0 miles/kWh
11.5¢/kWh	11.5¢/kWh
2.9¢/mile ↓76%	5.8¢/mile ↓73%

  - There are about 70 EV models in the US market in 2025

Electrification Projects

- **Monarch MK-V Electric Tractor**
  - Received December 21, 2023
  - Specs:
    - 40-70 hp equivalent
    - Cat I/II hitch, 540 rpm PTO, hydraulics
    - 8 to 10 hour run time
    - Autonomous capable!
  - Working with EPRI to fund implements for testing
  - Will monitor performance and energy use in comparison to diesel

What About **BIG** Tractors?

Energy Load - Electrification

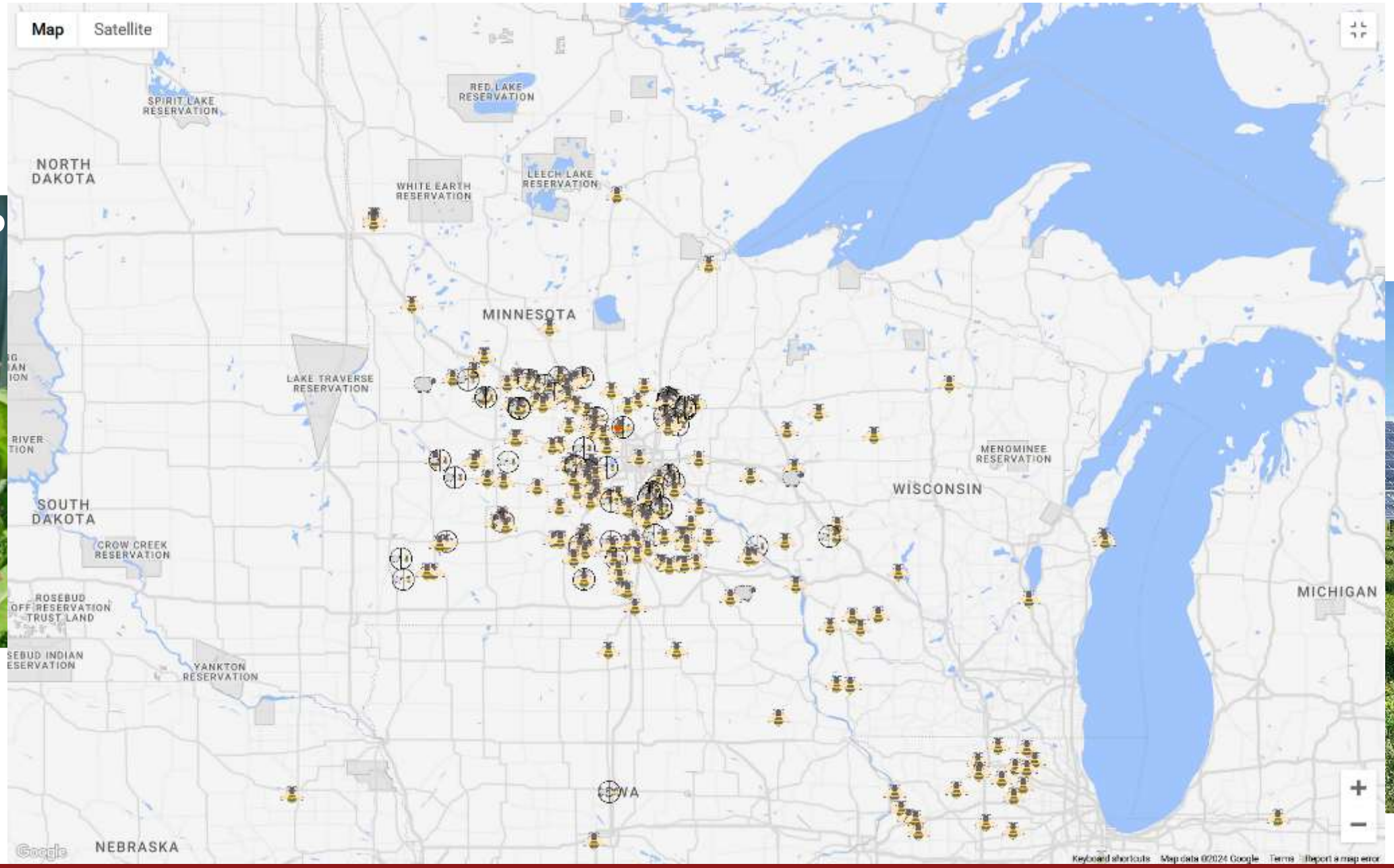
- **Weed Terminator**
  - Autonomous robot to weed row crops - Roomba® for a corn field!
  - GPS navigation and on-board cameras to help steer and identify corn/weeds
  - Weeds controlled mechanically – organic friendly
  - Battery powered, recharged with solar charging station

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Putting solar panels and traditional farming activities in the same place

Allows farmers to harvest the sun twice!!

AGRIVOLTAICS



INDIANA
PrairieFarmer

Solar factors into loss of prime farmland

People responding to articles about loss of farmland cite solar installations as another major threat.

The Rush for Solar Farms Could Make It Harder for Young Farmers to Access Land

Millions of acres of solar panels are needed to reach renewable energy goals. With established farmers being offered big bucks to turn ag into energy, will the next generation of farmers face another hurdle and be priced out?

BY ANNE MARSHALL-CHALMERS • APRIL 12, 2023

Insight: As solar capacity grows, some of America's most productive farmland is at risk

By P.J. Huffstutter and Christopher Walljasper

April 29, 2024 12:29 PM CDT · Updated 4 months ago

FARM - ARTICLE

Solar Projects on Farmland Meet Community Opposition in the Midwest

As communities look to green energy infrastructure, farmers and developers often find themselves on opposite sides of the deal.

#Accountability #Land

by Patrick Cooley · April 20, 2023

Maybe we’re looking at it the wrong way

What might a solar future look like?

- In 2021 average land in solar by US county was .04%
  - With all in queue solar built: .22%
- Providing 70% of MN electricity by 2050 would require 220,000 acres (22 gigawatts) of solar.
  - **This would be 1.32% of MN prime farmland!**

* Center for Rural Affairs, 2023. H. Kolbeck-Urlacher

- **And it doesn't all have to be prime farmland!**

Development principles as alternatives to land use restrictions

- **Prioritize solar siting on buildings and land not well suited for farming**
  - Including buildings, irrigation ditches, brownfields or other marginal lands.
- **Safeguard the ability for land to be used for agriculture**
  - If developed on farm or ranch land, policies and practices should protect soil health, especially during construction and decommissioning.
- **Grow agrivoltaics for agricultural production and solar energy**
- **Promote equity and farm viability**

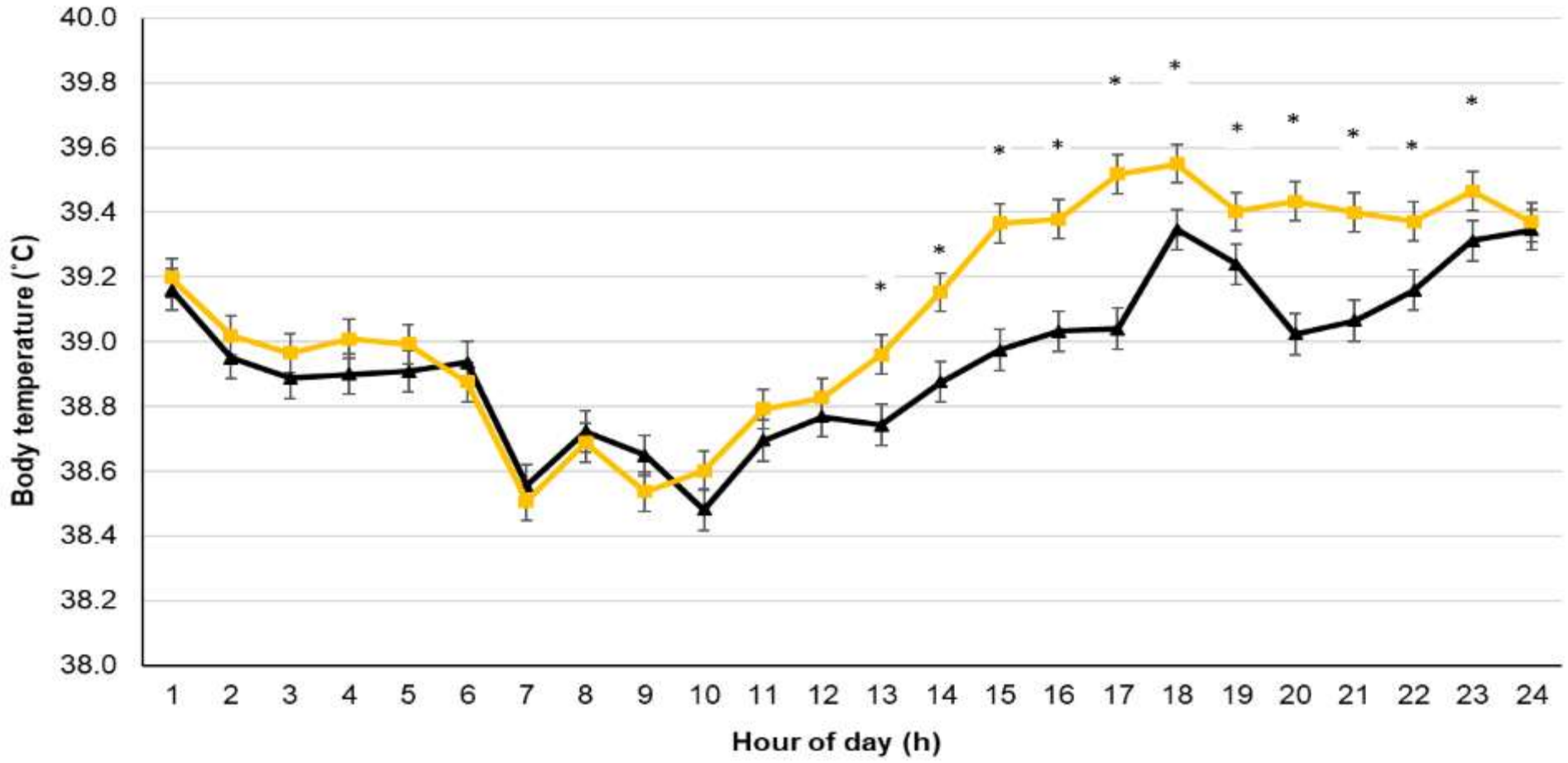
* Center for Rural Affairs, 2023. H. Kolbeck-Urlacher

Agrivoltaics at the WCROC

E.Buchanan MREC 2025

UNIVERSITY OF MINNESOTA
Driven to Discover

Body Temperature of Cows



Emerging Agrivoltaics

- **Mobile Solar Shade/Power Station (SSPS)**
  - Cows like shade, but grazing cows move
  - Mobile solar shade platform is designed for 25 cows with 18 kW of bifacial solar panels

Emerging Agrivoltaics

A group of MN farmers have designed a mounting system for putting a solar array in a traditional corn/soybean field.

- We will monitor environmental conditions
- Viability always comes down to cost and interconnection

40 kW on 10 poles w/dual axis tracking

E-FUELS

E-Fuels: Green H_2 & NH_3

N_2

H_2

NH_3

Advanced Fuels

- Nitrogen Fertilizer
- Tractor Fuel
- Truck Fuel
- Irrigation Generators
- Backup Generator
- Grain Dryer

Gensets – H_2 & NH_3

- 2G Hydrogen fueled CHP
  - Agenitor, 115 to 750 kW

- Current DOE grant
  - Dr. Will Northrup is developing a 200 kW genset running on pure ammonia
    - Delivery spring 2025

Green Ammonia is Transformational

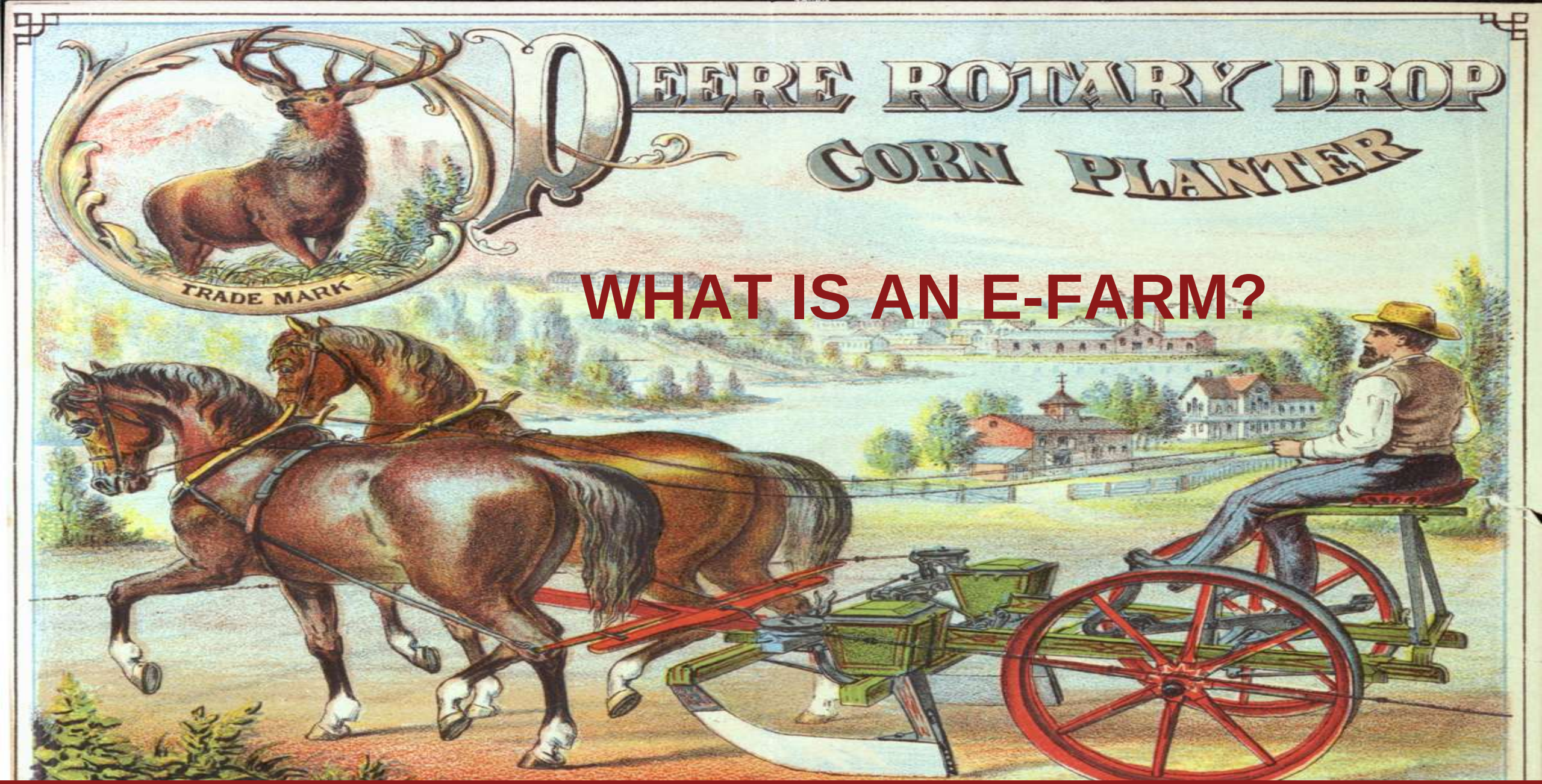
Potential to reduce fossil energy use in corn production over 90% using green ammonia (NH_3)

J. Tallaksen, 2016. UMN West Central Research and Outreach Center

The Big Ammonia Picture

CF Industries Glenwood Ammonia Terminal

- **Capacity of 60,000 tons of NH_3**
  - Equivalent to an estimated 111,000 MWh of electricity
- **Wind and solar PV near by**
- **Capex 500 kV line near by**



WHAT IS AN E-FARM?

Existing Energy Resources

- 1.65 MW wind turbine
- 130 kW solar PV
- Green H2 & NH3 production
- Natural gas & Diesel gensets

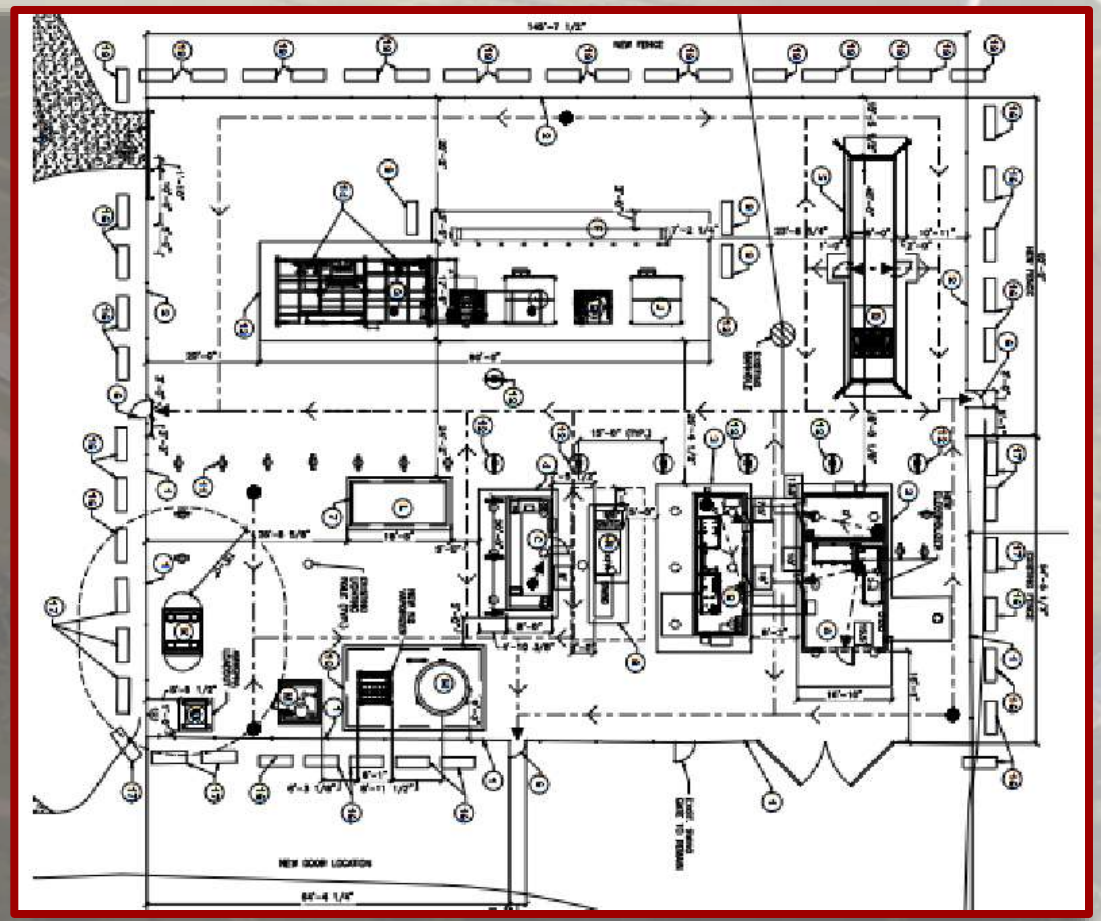
Morris, MN

E-Farm Aspirations

- Looking for ~4 MW of new solar (single axis tracking)
  - 2.5 MW in a 20-acre alfalfa field
    - Determine array spacing to allow field work and manure application
  - 1.5 MW in a 12-acre pasture
    - Optimizing cow management to reduce array costs
- New 3 MW wind turbine

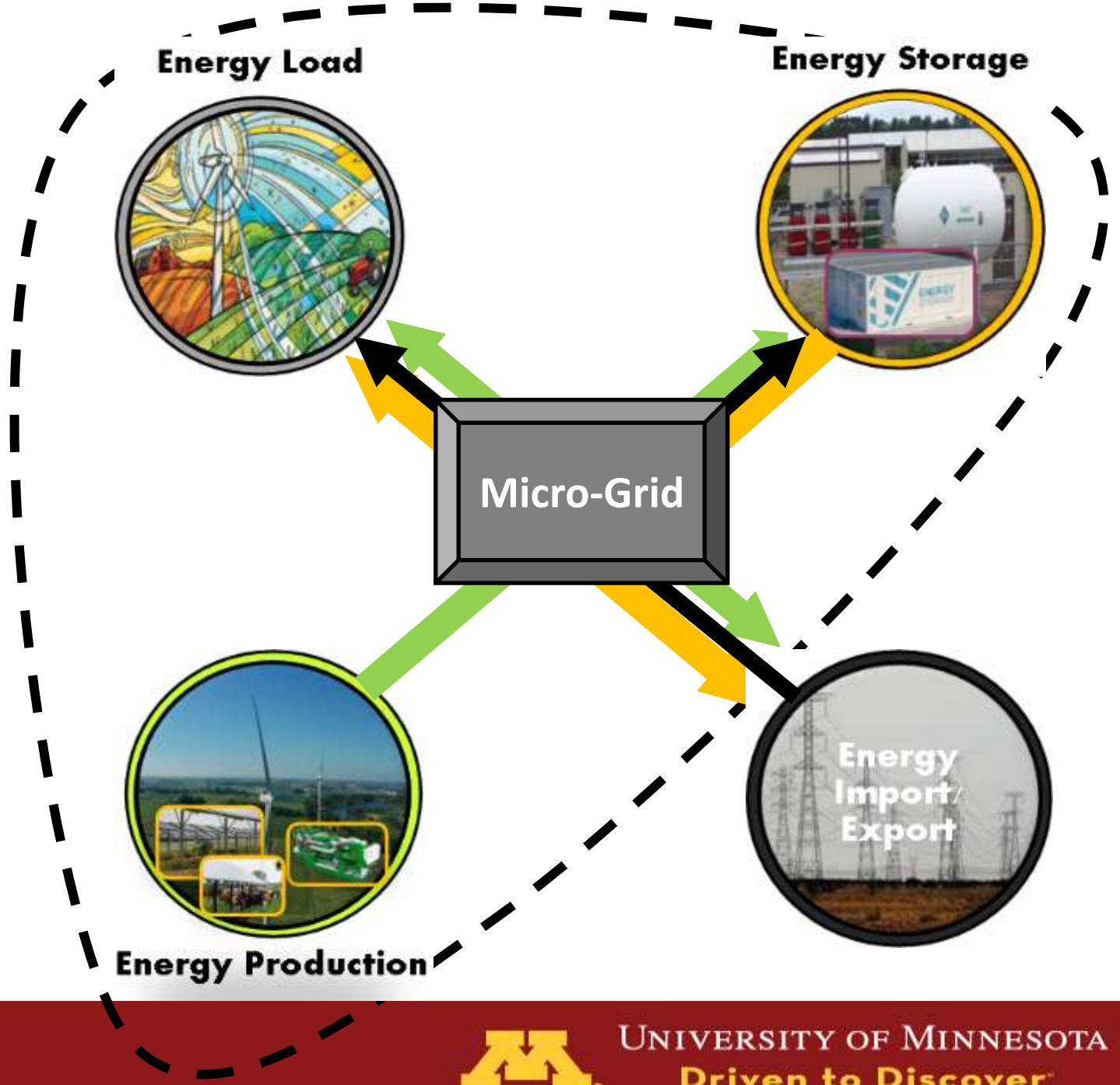
E-Farm Aspirations

- New green hydrogen/ammonia plant (>15x, in design)
  - New hydrogen and ammonia fueled generators
- ~1MW battery storage
- New substation on farm site
- Microgrid hardware and software



WCROC E-Farm

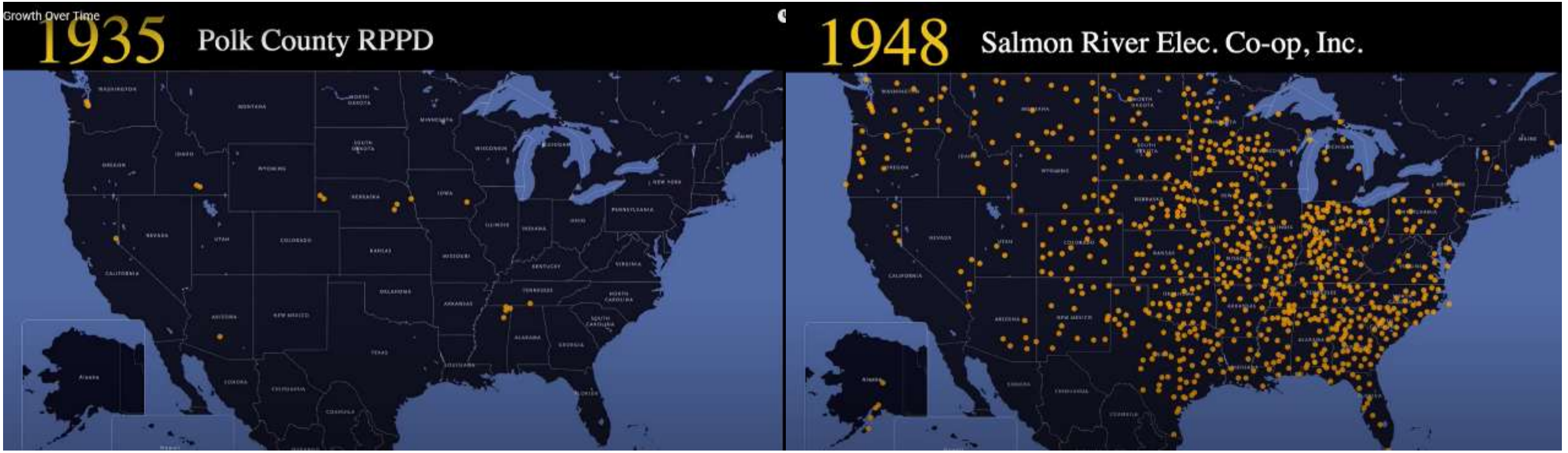
- Energy load: farm electrification and biofuels
- Energy production: agrivoltaics, wind, green H_2 & NH_3 gensets
- Energy storage: batteries and green H_2 & NH_3
- Energy import/export: Islanding and sale of grid services



Farm Electrification - When?

Rural Electrification Act (REA) signed in 1935 – 1 out of 10 farms have electricity

Exponential growth in 13 years. By 1953 9 out of 10 farms have electricity



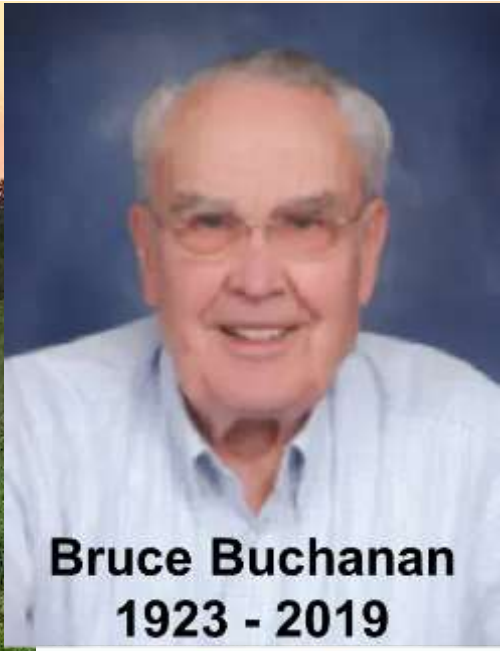
Easter morning 1900: 5th Ave, New York City. Spot the automobile.

Source: US National Archives.

Easter morning 1913: 5th Ave, New York City. Spot the horse.

Source: George Grantham Bain Collection.

Thank You



Eric Buchanan
Renewable Energy Program Director

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

UNIVERSITY OF MINNESOTA
Driven to Discover